national accelerator laboratory

TM-474
0402

DIPOLE MEASUREMENT DATA ANALYSIS

A.G. Ruggiero

February 20, 1974

Measurement Data

Although rather late, we have finally analyzed the data about field measurements of the main-ring dipoles.

We have analyzed the data of 348 "B1" magnets and of 219 "B2" magnets. All these magnets have been produced and measured before September 1972 and their ID numbers are less than 1270 and 1772 for the "B1" kind, and less than 2295 and 2783 for the "B2" kind.

Each magnet has a complete set of data. An example is shown below.

ID Number 1048

14.8	0.04	1.57	1.71	0.96	
15.0	0.04	1.54	1.71	0.93	(1)
14.7	0.05	1.54	1.71	0.96	

Each row corresponds to a location where the measurements were taken. The locations are, from up to down, x = + 1", x = 0" and x = - 1".

Each column corresponds to a DC excitation level. Measurements were taken at 9, 18, 21, and 22.5 kG (second column to the last one in the order) and, at the end of the cycle, when the excitation was turned off, the remanent field was also detected (first column). The first column is absolute measurement of the field in Gauss. The measurement error is ± 0.8 Gauss from magnet to magnet[1] and ± 0.1 Gauss within the same magnet[2]. The other columns are percent differences from the magnetic field, B_{ref}, in the center of the reference magnet. The measurement error in the differences is ± 0.03% from magnet to magnet[1] and ± 0.01% within the same magnet[2].

Observe that we disregarded the measurements of ± 1.5" in the "B1" magnets, as well the very few measurements at 0.4 kG (injection).

Analysis

Let us denote by b_{ij} (i = 1, 3 and j = 1, 5) an element of the matrix (1). For each magnet we also assume (arbitrarily) a vertical magnetic field on the "reference horizontal plane" of the type

$$B_y = B_0 + B' \, x + \frac{1}{2} B'' \, x^2 .$$

For each magnet and assigned excitation (j) we take

$$\begin{aligned} B_0 &= b_{2j} \\ B' &= \frac{b_{1j} - b_{3j}}{2} \\ B'' &= b_{1j} + b_{3j} - 2b_{2j} \end{aligned} \tag{2}$$

for the remanent field and

$$\begin{aligned} B_0/B_{ref} &= b_{2j} \\ B'/B_{ref} &= \frac{b_{1j} - b_{3j}}{2} \\ B''/B_{ref} &= b_{1j} + b_{3j} - 2b_{2j} \end{aligned} \tag{3}$$

at higher excitation.

The units are Gauss, Gauss/in and Gauss/in^2 in case (2) and in^0, in^{-1} and in^{-2} in case (3).

The measurement errors are ± 0.8 Gauss, ± 0.1 Gauss/in and ± 0.4 Gauss/in^2 in case (2), and ± 0.03 in^0, ± 0.01 in^{-1} and ± 0.04 in^{-2} in case (3).

At the end of the analysis we calculated averages (ave) and standard deviations (rms), and we recorded the minimum (min) and maximum (max) values.

The results are shown in Tables I to VI.

References

1. J. Schivell, TM-366 (April 1972)

2. C. Schmidt, private communication (1972)

Table I

Magnet type: B1

No. of magnets processed: 348

Quality tabulated: $\begin{cases} B_0\text{, for remanent field} \\ B_0/B_{ref}\text{, with excitation} \end{cases}$

	Rem	9 kG	18 kG	21 kG	22.5 kG
ave	17.2	-0.026	1.49	1.68	0.92
rms	1.3	0.084	0.082	0.077	0.084
min	12.9	-0.44	1.20	1.47	0.62
max	20.8	0.24	1.72	1.89	1.13
error(±)	0.8	0.03	0.03	0.03	0.03
unit	Gauss	%	%	%	%

Table II

Magnet type: B1

No. of magnets processed: 348

Quality tabulated: B', for remanent field; B'/B_{ref}, with excitation

	Rem	9 kG	18 kG	21 kG	22.5 kG
ave	0.018	-0.0008	-0.0013	-0.0007	0.0021
rms	0.068	0.005	0.006	0.005	0.009
min	-0.2	-0.035	-0.030	-0.015	-0.030
max	0.4	0.020	0.025	0.015	0.030
error(±)	0.1	0.01	0.01	0.01	0.01
unit	Gauss/in	%/in	%/in	%/in	%/in

Table III

Magnet type: B1

No. of magnets processed: 348

Quality tabulated: $\begin{cases} B'', \text{ for remanent field} \\ B''/B_{ref}, \text{ with excitation} \end{cases}$

	Rem	9 kG	18 kG	21 kG	22.5 kG
ave	-0.49	-0.002	-0.009	-0.005	0.066
rms	0.16	0.015	0.02	0.017	0.021
min	-1.2	-0.050	-0.080	-0.060	0.010
max	-0.1	0.070	0.040	0.050	0.130
error(±)	0.4	0.04	0.04	0.04	0.04
unit	Gauss/in^2	%/in^2	%/in^2	%/in^2	%/in^2

Table IV

Magnet type: B2

No. of magnets processed: 219

Quality tabulated: $\begin{cases} B_0\text{, for remanent field} \\ B_0/B_{ref}\text{, with excitation} \end{cases}$

	Rem	9 kG	18 kG	21 kG	22.5 kG
ave	13.7	0.16	1.49	1.94	1.84
rms	0.6	0.05	0.05	0.05	0.06
min	11.8	0.04	1.36	1.81	1.67
max	15.2	0.30	1.59	2.08	2.00
error(±)	0.8	0.03	0.03	0.03	0.03
unit	Gauss	%	%	%	%

Table V

Magnet type: B2

No. of magnets processed: 219

Quality tabulated: $\begin{cases} B', \text{ for remanent field} \\ B'/B_{ref}, \text{ with excitation} \end{cases}$

	Rem	9 kG	18 kG	21 kG	22.5 kG
ave	0.001	0.0001	-0.0004	-0.0002	0.006
rms	0.04	0.004	0.003	0.004	0.008
min	-0.15	-0.010	-0.010	-0.010	-0.015
max	0.15	0.050	0.010	0.015	0.025
error(±)	0.1	0.01	0.01	0.01	0.01
unit	Gauss/in	%/in	%/in	%/in	%/in

Table VI

Magnet type: B2

No. of magnets processed: 219

Quality tabulated: $\begin{cases} B'', \text{ for remanent field} \\ B''/B_{ref}, \text{ with excitation} \end{cases}$

	Rem	9 kG	18 kG	21 kG	22.5 kG
ave	-0.38	0.003	-0.001	-0.0003	0.088
rms	0.13	0.013	0.011	0.013	0.017
min	-1.0	-0.10	-0.04	-0.04	0.02
max	-0.1	0.04	0.03	0.04	0.14
error(±)	0.4	0.04	0.04	0.04	0.04
unit	Gauss/in^2	%/in^2	%/in^2	%/in^2	%/in^2